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Perceptual bias, more than age, impacts on eye movements during face processing.

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ABSTRACT

Consistent with the right hemispheric dominance for face processing, a left perceptual bias (LPB) is typically demonstrated by younger adults viewing faces and a left eye movement bias has also been revealed. Hemispheric asymmetry is predicted to reduce with age and older adults have demonstrated a weaker LPB, particularly when viewing time is restricted. What is currently unclear is whether age also weakens the left eye movement bias. Additionally, a right perceptual bias (RPB) for facial judgments has less frequently been demonstrated, but whether this is accompanied by a right eye movement bias has not been investigated. To address these issues older and younger adults' eye movements and gender judgments of chimeric faces were recorded in two time conditions. Age did not significantly weaken the LPB or eye movement bias; both groups looked initially to the left side of the face and made more fixations when the gender judgment was based on the left side. A positive association was found between LPB and initial saccades in the freeview condition and with all eye movements (initial saccades, number and duration of fixations) when time was restricted. The accompanying eye movement bias revealed by LPB participants contrasted with RPB participants who demonstrated no eye movement bias in either time condition. Consequently, increased age is not clearly associated with weakened perceptual and eye movement biases. Instead an eye movement bias accompanies an LPB (particularly under restricted viewing time conditions) but not an RPB.

Keywords: eye movements; perceptual bias; ageing; chimeric faces

Classification codes: 2323, 2330, 2340, 2346

1. Introduction

In general, faces appear approximately symmetrical along the vertical axis with the left and right sides typically revealing no discernible differences. However, research has consistently demonstrated that judgments of similarity, gender, age, attractiveness and emotional expression are based on facial cues seen to the viewer's left (Bourne, 2011; Burt & Perrett, 1997; Gilbert & Bakan, 1973). For example, when asked to judge the gender of a chimeric face – a constructed image where the left and right sides differ with regard to the gender shown – judgments are typically based on information presented in the left visual field, even when faces are inverted (Parente & Tommasi, 2008). The predisposition to base decisions on the left side is known as the left perceptual bias (LPB) and some research using eye tracking has shown an association between the LPB and a left eye movement bias. The left eye movement bias is the tendency to generate initial saccades to the left side, which has been described as a reflex response when faces are viewed (Leonards & Scott-Samuel, 2005), and for fixations to be more frequent and last for longer to the left side. This may be due to right hemispheric superiority for face processing (Kanwisher, McDermott & Chun, 1997; McCarthy, Puce, Gore & Allison, 1997), or could reflect more domain general processing as a left eye movement bias has also been noted using non-face stimuli such as photographs of indoor and outdoor scenes (Foulsham, Gray, Nasiopoulos & Kingstone, 2013; Nuthmann & Matthias, 2014). Alternatively it may, in part, be an artifact of the habituated left-right scanning direction practiced in the West for reading, writing and music, as this bias reduces in cultures where a right-left scanning is the norm (Vaid & Singh, 1989; Megreya & Havard, 2011).

Research investigating the link between biases of perception and attention during face processing is in its infancy. Some studies indicate that eye movements and the LPB appear to be associated when viewing faces. For example, it has been noted that when eye movements are not possible, due to viewing time being restricted, only 55% of gender judgments were based on the left side of the face (Butler & Harvey, 2006); however, when no limits to eye movements were imposed in a freeview condition 63% are based on the left side (Butler et al., 2005) which indicates that eye movements act to enhance the strength of the LPB. As the LPB is associated with greater activity and volume in RH structures (Kanwisher et al., 1997; McCarthy et al., 1997), and the LPB appears to be strengthened by eye movements, these findings potentially indicate that left lateral biases of attention and perception use the same neural circuits. However, the link between perceptual and eye movement biases during face processing is not conclusive. In a recent study chimeric and whole faces were presented individually at the top, bottom, left or right of screen, rather than in the centre as with Butler's various experiments (Samson, Fiori-Duharcourt, Doré-Mazars, Lemoine & Vergilino-Perez, 2014). When one saccade was permitted an LPB was only apparent for the face presented at the top of the screen and analysis of eye gaze revealed a right bias for the face presented on the left and a left bias for the face on the right. Consequently, gaze was biased to the side of the face closest to the centre of the screen and no direct link between perception and eye movements was established. As with Butler et al. (2005), Samson and colleagues investigated eye movements when the decision was based on the left and right side. A similar number of saccades were made to each side irrespective of the side used for a decision and as such their results demonstrate no consistent association between lateral biases of perception and attention.

Although the association between perceptual and eye movement biases appears somewhat equivocal, the LPB is a robust phenomenon considered to reflect right hemisphere superiority for face processing (Kanwisher et al., 1997; McCarthy et al., 1997) and support for this view is found from studies of patients who have sustained right hemispheric trauma. These patients consistently reveal deficits in face processing which are not detected in left hemisphere damaged patients (Bava, Ballantyne, May & Trauner, 2005; Kolb, Milner & Taylor, 1983). However, it has been argued by Cabeza (2002) and Park and Reuter-Lorenz (2009), that ageing impacts on lateralized hemispheric specialties such as face processing. Cabeza et al. (1997) noted that in functional neuroimaging studies of participants conducting verbal recall tasks - a task typically dominated by the right hemisphere - the prefrontal cortex was more bilaterally activated in older adults. The interpretation offered by Cabeza et al. is that this indicates functional compensation in later life and this forms the basis of the Hemispheric Asymmetry Reduction in OLDer adults (HAROLD) model (Cabeza, 2002). Cabeza also argues that the HAROLD model could be extended to include temporal and parietal regions because face matching (Grady, McIntosh, Horwitz & Rapoport, 2000) and face recognition (Grady, Bernstein, Beig & Siegenthaler, 2002) studies reveal greater bilateral activity in these areas in older compared to younger adults. The Scaffolding Theory of Ageing and Cognition (STAC) proposed by Park and Reuter-Lorenz (2009) similarly predicts that a wider, more generalised processing network across both hemispheres acts to scaffold or support specialist processing regions in an adaptive brain. Consequently, as these two models are aligned in predicting greater symmetrical processing across both hemispheres in healthy older adults, such adults may also demonstrate more symmetrical eye movement patterns and perceptual judgments than young adults when completing face processing tasks, particularly if these two processes rely on the same neural circuits.

To date no studies have assessed the impact of ageing on lateral eye movement biases, and the few studies that have examined the effect of ageing on perceptual biases have produced somewhat mixed evidence. For example, when Levine and Levy (1986) and Moreno, Borod, Welowitz & Alpert (1990) asked older and younger participants to judge the emotional intensity of happy/neutral chimeric faces, no significant age differences in LPB were revealed. All age groups demonstrated a bias to the left. Similarly, it has been found (Coolican, Eskes, McMullen & Lecky, 2008) that both younger and older adults demonstrated an LPB to happy/neutral chimeric images with no significant difference in the strength of bias between the groups. However, in contrast when participants aged 20 to 70 years judged the emotional intensity of happy/neutral chimerics, it was the oldest adults who demonstrated the weakest LPB, although non-significantly so (Cherry, Hellige & McDowd, 1995). This trend was more recently echoed in Failla, Sheppard and Bradshaw’s (2003) study. They found that from a group of participants aged 5-70 years, only those in the oldest group did not demonstrate an LPB. The same effect has also been revealed with older (mean age 72) and younger participants (mean age 22) in a study employing gender chimerics, particularly when task difficulty was increased through limiting the viewing time (Butler & Harvey, 2008).

Additionally, the strength of LPB appears to vary across the general population as up to 45% of gender judgments have been noted to be based on the right side (Butler & Harvey, 2006; Butler et al., 2005). Similarly, the leftward bias for eye movements is not revealed in all participants as some researchers have found approximately 34% of initial saccades are made to the right when faces are viewed

(Guo , Smith, Powell, & Nicolls, 2012). Indeed Leonards and Scott-Samuel (2005) found that approximately 40% of their participants made their initial saccades to the right when viewing faces. Some researchers report an association between leftward facial judgments and leftward eye movements (Butler et al., 2005) while others do not (Samson et al., 2014) and no exploration of right perceptual bias (RPB) and eye movements during facial analysis has been documented.

We sought to shed light on these inconsistencies by using eye-tracking to provide a more detailed analysis of face processing differences in older and younger adults and to investigate whether people demonstrating a RPB also demonstrate a right eye movement bias. Using chimeric faces, we asked participants to judge each image's gender either in a limited or unlimited time condition. In addition to analysing participants' perceptual biases, we measured the direction of their initial saccade and the proportion and duration of fixations to each face side. Using faces presented centrally on screen, we predicted that an association between the LPB and left eye movement bias would be revealed, such that people who based their gender judgment on the left side of the chimeric face would also generate initial saccades, proportionally more fixations and fixations of greater duration to the left side too. Due to age-related reductions in hemispheric asymmetries, we also predicted that age would weaken the LPB, the overall number of leftward eye movements and the length of time spent looking to the left face side. Additionally, based on Butler and Harvey's (2008) findings, we anticipated that the greater demand imposed by limiting the viewing time would have a bigger impact on the older group, as speed of processing reduces in later life (Habekost et al., 2013). Consequently, when viewing time was limited, we anticipated that older adults would reveal a further weakening of their left perceptual and eye movement biases compared with younger adults. A final goal was to determine whether the associations between perception and eye movements for participants demonstrating a RPB mirrored the relationships shown by those with LPB.

2. Method

2.1. Participants

To minimise the effects of fatigue and learning, separate cohorts were recruited for each of the time conditions.

2.1.1 Freeview condition

Sixty three right handed adults participated in this condition, 31 older adults (7 males) with a mean age of 65.10 (*SD* = 4.28, range 60-84 years) and 32 younger adults (9 males) with a mean age of 19.47 (*SD* = 2.30, range 18-28 years). Laterality quotient computed using the Edinburgh Handedness Inventory (Oldfield, 1971) revealed group differences with older adults demonstrating higher right laterality (*M* = 93.45, *SD* = 10.27) than younger adults (*M* = 86.63, *SD* = 13.33, $t(61) = -2.27$, $p = .027$). National Adult Reading Test (NART; Nelson, 1982) results also indicated group differences with older adults scoring higher (*M* = 37.87, *SD* = 8.90) than younger adults (*M* = 26.88, *SD* = 5.60, $t(50.25) = -5.85$, $p < .001$), although no group differences were revealed for years spent in full time education for older (*M* = 15.26, *SD* = 3.47) or younger adults (*M* = 14.22, *SD* = 1.64), $t(42.45) = -1.51$, $p = .138$).

2.1.2 Time limited condition

Fifty two participants were initially recruited for this viewing condition; however, data from three older adults were removed due to difficulties in calibrating their eye movements. Data for three younger adults were also removed due to poor accuracy in judgments of single gender images (20% correct), being left-handed and failing to complete the task. Consequently, the data of forty six right-handed adults were included; 22 older (7 males) with a mean age of 66.50 (SD = 4.02), range 60-74 years) and 24 younger adults (3 males), mean age 20.46 (SD = 2.15, range 18-26 years). Laterality quotient computed using the Edinburgh Handedness Inventory (Oldfield, 1971) revealed no group differences between the older (M = 85.45, SD = 15.17) and younger adults (M = 85.50, SD = 17.53, $t(44) = -.01$, $p = .993$). The National Adult Reading Test (NART: Nelson, 1982) did not reveal age group differences (older; M = 34.82, SD = 6.78, younger; M = 35.75, SD = 3.61, $t(31.42) = -.57$, $p = .570$). Group differences were, however, revealed for education with older adults spending fewer years in full time education than younger adults (older; M = 12.55, SD = 2.61, younger; M = 15.79, SD = 1.38, $t(31.28) = -5.20$, $p < .001$).

2.2. Stimuli

The stimuli consisted of those used previously by Butler et al., (2005) and comprised 40 faces: ten male, ten female, ten left female/right male chimeric faces and ten left male/right female chimeric faces. See Burt and Perrett (1997) and Butler et al. (2005) for details of image composition and construction.

2.3. Apparatus

This experiment was conducted on a desk top computer attached to a 19 inch Viewsonic monitor with the resolution set at 1280 x 1064 pixels and a refresh rate of

85 Hz. A response pad was situated on the participant's mid-sagittal axis with two response keys aligned vertically. The response keys were counterbalanced between participants and responses were only made with the participants' dominant right hand. The displays were controlled by Experiment Builder software version 1.1.1 (SR Research Ltd., Ontario, Canada). Eye movements were recorded using an Eyelink II eye-tracker (SR Research Ltd., Ontario, Canada) at 500Hz sample rate and at a spatial resolution, typically of .01°. Saccade onset was defined as a change of eye position with a minimum velocity of 22°/s or minimal acceleration threshold of $8000°/s^2$.

2.4. Procedure

Participants were tested individually with a computer screen positioned centrally 57 cm in front of them and a chin rest maintained a stable head position. A total of five blocks of trials were completed. In each block all forty images were presented once in a random sequence, with each face individually positioned in the centre of the screen at a visual angle of 20° x 20°. Following calibration and validation procedures at the start of each trial block, a forced choice task required participants to judge the gender of each image. The presentation of each face was preceded by a central fixation point with a diameter of 0.3°. When fixation was stable, stimulus onset was activated, and using the index finger and thumb of their right hand, participants made either a male or female response choice. In the freeview condition the image remained on the screen until a response was made, in the time limited condition each image remained for 1000ms after which participants responded. Eye movement data were collected binocularly, however, analysis was only conducted on the eye with the best spatial accuracy as assessed through validation for each block.

2.5. Analysis procedure

Firstly the impact of age on perceptual bias and eye movements was examined. Additionally, as strength of LPB was anticipated to vary in both age groups on a continuum from basing the majority of judgments on the left side through to basing the majority of judgments on the right, we also examined the association between lateralization of perceptual bias and lateralization of eye movements.

3. Results

In accordance with previous literature (Wenban-Smith & Findlay, 1991), trials in which participants generated their first saccade earlier than 80ms after stimulus presentation were removed. Trials were also removed if participants fixated more than 1° from the central fixation point prior to stimulus onset to ensure that off-centre fixations did not lead to saccades being generated in the same direction. These procedures led to 960 (7.62%) trials being removed from the freeview condition and 1,336 (10.6%) trials being removed from the time restricted condition.

3.1 Accuracy rates for single gender images

As has been noted (Butler & Harvey, 2008) accuracy for the single gender faces in this task is less than perfect due to the somewhat androgynous appearance of the stimuli. However, one-sample *t*-tests against .5 (chance), revealed accuracy was significantly higher than chance for the younger adults in the freeview (M = .87, SD =.04; $t(31) = 55.78$, $p < .001$ $r = 1.00$) and limited time conditions (M = .84, SD =.05; $t(23) = 36.39$, $p < .001$ $r = .99$). Accuracy was also significantly higher than chance for older adults in the freeview and time limited conditions; (M = .85, SD =.04; $t(30)$ = 43.98, p < .001 r = .99) and (M = .78, SD =.09; $t(21)$ = 15.01, p < .001 r = .96) respectively. Therefore, as participants were easily able to detect the gender of the single gender images, their judgments of the male-female and female-male chimeric faces were taken as indicators as to the side they used to make their decision. As the primary aim of this experiment was to examine eye movement patterns and judgments to chimeric stimuli, no further analysis of the single gender images are detailed.

Insert Table 1 near here.

3.2 Perceptual bias

The mean proportion of judgments made according to the left side of the chimeric face was calculated for each participant. A mean greater than .50 indicated a bias to respond according to the left side of the face and a mean less than .50 to the right. One sample *t*-tests against chance (.5) were then conducted for each age group in each time condition. As illustrated in Table 1 a significant LPB where the left side of the face was used to make the gender decision was evident for the younger adults in both freeview ($t(31)$ = 2.95, p = .006, r = .47), and time limited conditions ($t(23)$ = 2.91, p = .008, r = .52). The older adults showed an LPB under the freeview condition ($t(30)$ = 3.02, p = .005, r = .48) but failed to demonstrate a statistically significant effect when stimulus exposure time was limited ($t(21)$ = 1.97, p = 0.062, r = .39). It should, however, be noted that the strength of perceptual bias (53%) was the same for older participants in the freeview and time limited condition, therefore the non-significant result in the 1000ms condition could reflect differences in group size or variance.

To assess whether age or viewing time influenced the extent of the leftward judgment bias a two way independent ANOVA (Age x Time Condition) was then conducted. This revealed no significant main effects of age ($F(1,105) = 1.68$, $p = .197$, $\eta_p^2 = .02$), or time condition ($F(1,105) = .002$, $p = .965$ $\eta_p^2 = .00$), or interaction ($F(1,105) = .06$, $p = .803$ $\eta_p^2 = .00$).

3.3 Initial saccades

The mean proportion of initial saccades generated to the left side of the chimeric face was calculated for each participant, and to determine whether older and younger adults demonstrated a lateral bias for their initial saccades one-sample *t* statistics against .5 (chance) were conducted for each time condition (Table 1). A significant bias to generate initial saccades to the left was revealed in the freeview condition for the older ($t(30) = 2.69$, $p = .012$, $r = .44$) and younger adults ($t(31) = 2.23$, $p = .033$, $r = .37$). A significant leftward saccade bias was also revealed in the time limited condition for older ($t(21) = 2.11$, $p = .047$, $r = .42$) and younger adults ($t(23) = 2.77$, $p = .011$, $r = .50$) See Figure 1. An independent ANOVA assessing the effect of age and time condition on the mean proportion of initial saccades generated to the left side of the chimeric faces revealed no significant main effects for age ($F(1,105) < .000$, $p = .998$, $\eta_p^2 = .00$), or time condition ($F(1,105) = .01$, $p = .910$, $\eta_p^2 = .00$) or interaction ($F(1,105) = .18$, $p = .669$, $\eta_p^2 = .00$).

<u>Insert Figure 1 near here</u>

The lack of significant age group differences within these analyses could arise from there genuinely being no differences between the older and younger adults, or from high levels of variance in the data due to the sampling procedures or the paradigm used. To evaluate these two possibilities Bayes factors were estimated (Dienes, 2008). A Bayes factor of less than .3 is considered to provide strong evidence to support the null hypothesis, and a value above 3 strong evidence for the experimental hypothesis. Values in between these two limits indicate that data arising from the experimental procedure are not sufficiently sensitive to accept or reject either hypothesis. To calculate the Bayes factors for the group differences in the left perceptual biases the mean differences between the older and younger groups were obtained. For the freeview condition this was .016 (*SE* of the difference = .02) and for the time restricted condition .024 (*SE* of difference = .03). Butler and Harvey (2008) using the same stimuli reported a mean perceptual bias of .58 (*SD* = .11) for younger adults, therefore, we modelled the Bayes factors as a half normal with a mode of 0 and SD of .11[1]. This yielded a Bayes factor of .38 for the freeview condition indicating strong evidence for a lack of difference in the perceptual bias between the younger and older adults. However, the Bayes factor for the time restricted condition was .55 which indicated that no clear conclusion could be drawn about age group differences from these data. For the analysis of the initial saccade data there were no previous studies that we could use to estimate the SD of the distribution, therefore we modelled this using the SD for the younger adults in the freeview condition (.30). This yielded Bayes factors of .33 for both the freeview and time limited conditions, indicating strong support for there being no differences between the younger and older adults in the tendency to make an initial saccade to the left when presented with a chimeric face.

[1] http://www.lifesci.sussex.ac.uk/home/Zoltan_Dienes/inference/Bayes.htm

3.4 Proportion of fixations when gender judgments were made to either the left or the right side of the face

Since the number of fixations varied on each trial, the proportion of leftward fixations for each trial was calculated. Separate averages were then calculated for trials where the gender judgment was based on the left side of the face (freeview younger *M* = .54, *SD* = .10, older *M* = .51, *SD* = .13; 1000ms younger *M* = .51, *SD* .11, older *M* = .53, *SD* = .16). and for the right side of the face (freeview younger *M* = .50, *SD* = .11, older *M* = .48, *SD* = .14; 1000ms younger *M* = .52, *SD* .12, older *M* = .50, *SD* = .20). To determine whether the side of the chimeric face used to make the perceptual judgments was accompanied by more fixations to that side of the face one-sample *t*-tests were conducted against chance (.5). This revealed that when judgments were based on the left side in the freeview condition, younger adults made proportionally more fixations to the left side ($t(31) = 2.42$, $p = .022$, $r = .16$). No other significant lateral biases were revealed (all p >.380).

A mixed ANOVA (Age x Side x Time Condition) revealed that the main effects of age ($F(1, 105) = .30$, $p = .586$, $\eta_p^2 = .003$) and time condition were non-significant ($F(1, 105) = .05$, $p = .823$, $\eta_p^2 < .001$) and age did not significantly interact with face side or time (*p*s > .070). A significant main effect of face judgment side was revealed with decisions based on the left side receiving significantly more fixations than decisions based on the right side of the face ($F(1,105) = 7.27$, $p = .008$, $\eta_p^2 = .07$).

To determine whether the non-significant effect of age on proportion of fixations should be accepted, Bayes factors were calculated in each time condition. Consistent with the initial saccade analysis, the SD of the younger group in each time condition was used to estimate distribution (freeview, *SD* = .11, 1000ms, *SD* = .10).

Using a mean difference of -.03 (*SE* of the difference = -.03) in the freeview condition a Bayes factor of .72 was calculated suggesting that no clear conclusions could be drawn in this time condition. Using a mean difference of -.005 (*SE* of the difference = -.04) in the time restricted condition a Bayes factor of .39 was calculated providing quite strong evidence for the null hypothesis that age did not impact of the proportion of fixations generated to each face side in this time condition.

3.5 Durations of fixations when gender judgments were made to either the left or the right side of the face

Mean fixation durations to the left and right side of the face were calculated for trials where the perceptual judgments were made on the left and right side of the chimeric faces. A four-way mixed ANOVA was conducted to determine whether age, viewing time condition, face side or side of response impacted on fixation duration. The main effect of age was approaching the level of significance ($F(1, 105) = 3.81$, $p = .054$, $\eta_p^2 = .04$), with a trend for older adults to have a longer mean fixation duration (ms) than the younger adults ($M = 779$, $SE = 62$ vs $M = 610$, $SE = 60$). As expected there was a significant main effect of time condition ($F(1, 105) = 71.12$, $p < .001$, $\eta_p^2 = .40$) with a longer mean fixation duration (ms) in the freeview compared with 1000ms condition ($M = 1061$, $SE = 56$, vs $M = 328$, $SE = 66$). No other main effects were significant (*p*s > .061) and age did not significantly interact with time condition, face side, or side of response (*p*s > .064).

A Bayes estimate for age differences in mean duration of fixations to the left side of the face in the freeview condition was calculated as 1.09 using the younger group's SD of 387ms (mean difference = 270, *SE* of the difference = 406), offering a lack of confidence in accepting the null hypotheses. The Bayes estimate for the

1000ms condition, using the younger group's SD of 72ms (mean difference = -3.15, *SE* of the difference = -24) was .35 which strongly supports a lack of difference between the age groups in the duration of fixations to the left. For age differences for duration of fixation to the right side of the face in the freeview condition (using the younger group's SD of 411ms, mean difference = 398, *SE* of the difference = 168) the Bayes factor was 8.26 indicating a clear difference between the age groups, with the older group fixating longer. In the 1000ms condition the younger group's SD of 81ms (mean difference = -11, *SE* of the difference = 29) was used to calculate a Bayes factor of .47 from which no clear conclusions of the effect of age on the duration of fixation to the right side of the face can be drawn.

In summary these analyses showed that older adults exhibited a tendency to fixate for longer than younger adults that was approaching statistical significance. In the freeview condition the Bayes analyses revealed that the null hypothesis for older and younger adults fixating to the left for equal durations could not confidently be accepted, but there was a clear age group differences for fixation duration to the right side with the older group fixating for longer than the younger group.

3.6 Relationships between perceptual and eye movement biases

Given the lack of significant age related differences in perceptual or eye movement biases data from the two groups were collapsed and the associations between perceptual bias, handedness, age and eye movements were examined. Table 2 shows that in the freeview condition a significant positive correlation was revealed for the direction of the perceptual bias and initial saccades (p = .035), but no other significant correlations were found (ps > .231). When viewing time was limited to 1000ms direction of the perceptual bias was significantly and positively correlated with the direction of the initial saccades (p = .021), proportion of fixations (p = .001) and the mean duration of fixations to the left side of the face (p < .001). No significant correlations were revealed for handedness (p = .775) or age (p = .479). The association between perceptual bias and initial saccades for participants across both time conditions is illustrated in Figure 2.

Insert Table 2 near here

Insert Figure 2 near here

3.7 Right perceptual bias

As anticipated, strength of LPB varied in both groups. Indeed a substantial number of participants demonstrated a right perceptual bias (RPB); over 20% of participants across both age groups (22% freeview and 27% 1000ms).

The full cohort of older and younger participants across both time conditions (n = 109) demonstrated a range in perceptual judgment bias of .30 to .77. Fourteen participants showed negligible, or no bias, with proportions of judgments to the left in the range of .49 to .51. These participants were not included in the following analyses. Based on the remaining 95 participants three bias groups were created. Participants with a strong left bias, demonstrated by their perceptual bias mean of ≥.61, participants with a weak left bias, revealed through a range of .52 to .60 and participants with a right bias ≤ .48.

The strong left perceptual bias group contained 22 adults; 4 older and 8 younger from the freeview condition (M = .67, SD = .04, range .62 - .75), 4 older and 6 younger from the time restricted condition (M = .66, SD = .05, range .61 - .77). Forty nine participants were included in the weak left perceptual bias group 15 older and 15 younger in the freeview condition (M = .55, SD = .02, range .52 - .60) and 7 older and 12 younger in the limited viewing (*M* = .56, *SD* = .02, range .52 - .59). The right perceptual bias group comprised 24 participants, 6 older and 6 younger from the freeview condition (*M* = .43, *SD* = .05, range .29 - .48) and 6 older and 6 younger from the limited time condition (*M* = .43, *SD* = .05, range .30 - .48). Confirmatory one-sample *t*-tests against chance were conducted and confirmed that each group were significantly biased in their judgments.

To establish if the initial saccade was made in the direction of the judgment bias, additional one sample *t*-tests were conducted against .5 (chance). As Table 3 illustrates the strong left bias group in the freeview condition ($t(11) = 2.44$, $p = .033$, $r = .59$) and time restricted condition ($t(9) = 2.58$, $p = .030$, $r = .65$) generated a significantly greater proportion of initial saccades to the left compared to chance. The weak left bias group showed the same pattern in both time conditions; freeview ($t(29) = 2.34$, $p = .026$, $r = .40$) and limited ($t(18) = 2.89$, $p = .010$ $r = .56$). However, the initial saccades of the right bias group approximated an equal 50/50 distribution to the left and right sides of the face in both the freeview ($t(11) = -.08$, $p = .941$, $r = .02$) and limited time conditions ($t(11) = .18$, $p = .859$, $r = .05$). Consequently, whilst all three groups demonstrated lateralized perceptual biases when compared against chance, only participants who biased their gender judgments to the left side showed an association between judgments and initial saccades. The right perceptual bias group did not show this association between judgment and initial saccades.

<u>Insert Table 3 near here</u>

Based on the side of the face used to make the gender decision the proportion of leftward fixations was also examined and uncorrected one-sample *t*-tests against .5

(chance) were conducted. As shown in Table 4 the strong LPB group had a greater proportion of leftward fixations when they based their decision on the left side of the face in the time restricted condition ($t(9) = 2.68$, $p = .025$, $r = .44$), all other results were non-significant (ps > .104).

Insert Table 4 near here

The results of a mixed (Group x Response Side x Time Condition) ANOVA revealed a main effect of response side $F(1,89) = 10.79$, $p = .001$, $\eta_p^2 = .11$ with responses based on the left receiving significantly more fixations compared to responses based on the right ($M = .52$, $SE = .01$ and $M = .50$ $SE = .01$). A significant main effect of group was also found $F(2,89) = 4.89$, $p = .010$, $\eta_p^2 = .10$ and Bonferonni post hoc comparisons revealed that the strong left bias group made significantly more leftward fixations than the right bias group ($M = .56$, $SE = .03$ and $M = .46$, $SE = .02$, $p = .003$). The weak left bias group also made significantly more leftward fixations than the right bias group ($M = .52$, $SE = .02$ and $M = .46$, $SE = .02$, $p = .030$), but the strong and weak left bias groups did not differ significantly $p = .163$.

To determine whether group, response side, face side or time condition had a significant effect on fixation duration a mixed (3 x 2 x 2 x 2) ANOVA was conducted. Not surprisingly, a main effect of time condition was revealed with fixation duration being greater in the freeview ($M = 962$, $SE = 62$) than 1000ms time condition ($M = 330$, $SE = 67$; $F(1, 89) = 37.98$, $p > .001$, $\eta_p^2 = .30$). No significant main effects of response side (left $M = 644.53$, $SE = 51.43$, right $M = 662.62$. $SE = 54.28$; $F(1, 89) = 1.47$, $p = .223$, $\eta_p^2 = .02$), face side (left $M = 658.93$, $SE = 54.71$, right $M = 648.22$. SE

= 58.89; $F(1, 89) = .06$, $p = .809$, $\eta_p^2 = .001$) or group were revealed (strong left M = 569.56, SE = 101.84, weak left M = 759.29, SE = 69.73, right M = 631.87, SE = 97.10; $F(2, 89) = 1.35$, $p = .263$, $\eta_p^2 = .03$) see Table 5.

Insert Table 5 near here

4. Discussion

The aims of this study were to examine whether the LPB and left eye movement biases weaken with age and viewing time when gender judgments of chimeric faces are made, and to determine whether left and right perceptual biases are also accompanied by eye movement biases.

It was found that overall both age groups based their judgments on the left side of the face when viewing time was unlimited. This provides further evidence for an LPB, an effect which has consistently been demonstrated in face processing studies (Bourne, 2011, Burt & Perrett, 1997; Gilbert & Bakan, 1973; Parente & Tommasi, 2008). It also supports previous studies showing no effect of age on the LPB when faces are viewed for an unlimited time (Levine & Levy, 1986; Moreno et al., 1990; Coolican et al., 2008). This lack of age difference may in part be due to the majority of this older cohort being at the younger end of the older age group as18 older adults were aged 60-64 (*M* = 62.21, *SD* = 1.61), 7 were aged 65-69 (*M* = 66.29, *SD* = 1.11) and 7 were aged 70 and over (*M* = 74.00, *SD* = 4.94). The selection criteria were for right handed older adults to be aged 60 and over, and for participants to have no visual impairments or neurological disorders and therefore it is perhaps not surprising that the majority of those who chose to participate were the youngest of the older group. It has been noted that age related changes consistent with the HAROLD model have been found in older-old (*M* = 74.5 years), but not younger-old participants (*M* = 63.2 years; Nielson, Langenecker & Garavan, 2002). However, Failla et al., (2003) found the LPB of older adults (mean age 66) to be less pronounced than younger adults, a finding supported by Cherry et al.'s (1995) study which recruited an older group with a mean age of 70. It may, therefore, be beneficial for future researchers to consider recruiting participants aged 65, or even 70 and over, to ensure that any effects of age are exposed. In the time limited condition the younger adults persisted to bias their perceptions of gender to the left, whereas the older adults were not significantly different from chance. This is a similar finding to Butler and Harvey (2008) who reported a significant effect of age and time condition on LPB. However, Butler and Harvey reported the presence of an LPB in their older cohort when viewing time was restricted to 300ms, but not when it was reduced to 100ms, whereas the older adults in the current study showed a lack of bias at 1000ms. This is despite the mean proportion of LPB at .53 being the same in both the time restricted condition in the current study and Butler and Harvey's 300ms condition. There was, however, greater variability in leftward judgments for the current group compared with Butler and Harvey's (*SD* = .07 vs .05) which may account for this disparity. Even though a larger sample was recruited in the current study; 22 older and 24 younger participants in this study for the limited time condition, versus 14 older (mean age = 72, SD = 3.9) and 22 younger adults (22.1 SD = 2.3) in Butler and Harvey's experiment, it is possible that the samples contained different proportions of participants with either no bias or a right bias. It is also worth noting that the older participants recruited by Butler and Harvey had a higher mean age (*M* = 72, *SD* = 3.9) than those in this current study (*M* = 66.50, *SD* = 4.02), which could have a bearing on their LPB.

Additionally, Butler and Harvey adopted a within groups design which is arguably a more powerful design as any differences found between the time conditions cannot be attributed to group differences as may be the case with a between groups design. However, it could also be argued that as they adopted a within groups design, their older group's LPB was an effect of cohort rather than age.

This is the first study to track older adults' eye movements while they conducted a chimeric gender judgment task and the results clearly show a leftward bias with both age groups generating over 60% of their first saccades to the left in the freeview and time restricted conditions. This leftward bias has frequently been noted in the face processing literature (Mertens et al., 1993; Philips & David, 1997) and supports other studies showing such an effect for younger adults when judging gender (Butler et al., 2005), familiarity and emotional expressions (Guo et al., 2012). Additionally, as it is not necessarily related to perceptual judgments (Butler et al., 2005) a leftward bias for initial saccades is argued to be a reflexive action at the commencement of facial analysis (Leonards & Scott-Samuel, 2005). Consequently, for this reason and due to older adults having a more highly practiced left to right reading style, it was accurately anticipated that increased age would not result in fewer initial saccades being generated to the left overall.

Lateral biases were calculated against chance for proportion of fixations and each side of the face was directly compared for fixation duration. When the left side of the face was used in making the gender response, a greater number of fixations were also recorded indicating RH dominance for this task and supporting Butler et al.'s (2005) findings. This effect was particularly apparent in the freeview time condition offering partial support for Butler and Harvey's (2006) assertion that longer viewing times enhance left biased eye movements. However, full support for this argument is not revealed by the fixation duration data as the left and right sides were looked at for approximately the same duration in both time conditions, side of response did not impact on this. Potentially, this eye movement behaviour reflects atypical scanning as participants 'weigh up' the two sides of the chimeric face before reaching a decision, however, as left lateral eye movement biases have been revealed for both the proportion and duration of fixations using chimeric images previously (Butler et al., 2005) this interpretation should be treated with caution.

The data also showed that the older group did not demonstrate a lateral bias for proportion of fixations. At first glance this appears to support the theories of ageing (Cabeza, 2002; Park & Reuter-Lorenz, 2009), as such symmetrical eye movements for the older group were anticipated, but the data revealed no significant differences according to age. Thus, age did impact on perceptual bias as has been noted previously (Butler & Harvey, 2008; Coolican et al., 2008; Failla et al., 2003), but their eye movement behaviour indicates that facial scanning remains unaffected by advancing age.

The results also clearly show a positive association between eye movements and mean LPB proportions across both age groups. This contrasts with Samson et al.'s (2014) assertion that eye movements and perceptual judgements are not related, as initial saccades and perceptual bias were positively associated at freeview and, in addition, proportionally more fixations and fixations of greater duration were linked to perceptual bias when viewing time was restricted. These findings build on Butler et al.'s (2005) work as their group revealed left lateral eye movement and perceptual biases, but they did not assess whether the two biases were directly related as we have done here. The stronger relationship between eye movements and perceptual bias apparent in the 1000ms time condition appears to be due to the tendency to initially and preferentially focus on the side of the face used to make a decision. When no time constraints were imposed our findings show no link between the number or duration of fixations with perceptual bias. This suggests that a more equal exploration of each side of the face is enabled in the freeview time condition and as a consequence this eye movement behaviour is not related to the side used for a gender judgement.

Without the use of eye tracking, it has previously been speculated that longer viewing times increase the strength of LPB due to the reinforcing effect of eye movements (Butler & Harvey, 2008). While this effect may be apparent when comparing the shorter viewing time of 100ms to freeview as per Butler and Harvey's findings, our eye tracking data does not support these claims when comparing 1000ms to freeview. Potentially the LPB is strengthened by eye movements when viewing time is greater than 100ms as eye movements may not be possible at this time frame. Therefore eye movements strengthen the LPB until viewing time is of optimal length after which the strength of the LPB plateaus which is perhaps why we did not find that a strengthening effect from 1000ms to freeview. Presentation times of 1000ms and freeview were selected to enable sufficient eye movements to be generated by both age groups. Butler and Harvey (2006) used a 100ms presentation time condition and later (2008) 100ms, 300ms and freeview presentation times when assessing younger adults' perceptions of gender of chimeric images. These authors note that 100ms is pre-saccadic and therefore would not be suitable for this current study. The 300ms presentation time enables younger adults to produce up to approximately three eye movements, however, older adults would be anticipated to generate fewer, possibly only one eye movement within this time scale and therefore we selected a longer presentation time. Potentially a presentation time of 500ms may be used in addition with, or instead of, 1000ms when used to compare with the freeview condition in future research.

Interestingly the results showed that approximately a quarter of participants (6 older and 6 younger adults in each of the time conditions) demonstrated a bias to judge faces from the right side. Given that face processing is considered a right hemisphere dominant task, this rightward bias of perception seems counterintuitive. Some individual differences, such as left handedness, have been found to impact on the LPB (Bourne, 2008), but all participants in this study were right handed as assessed by the Edinburgh Handedness Inventory (Oldfield, 1971). It has previously been revealed that individual differences in state, trait and social anxiety affect lateralisation of emotion processing with high trait anxiety more strongly lateralising to the RH, and high social anxiety weakly RH or even LH lateralised (Bourne & Vladeanu, 2011). The participants in this current study were recruited randomly and therefore there is no reason to believe that they were high in any of these types of anxiety. However, as research into individual differences for lateralisation of facial processing is relatively new, the causes of lateral processing differences have only just started to be explored. While it would be reasonable to expect participants to vary slightly in their degree of leftward bias a reversed right perceptual bias was not expected in such a large number of participants.

It is possible that the left hemisphere has greater input for spatial representation for some individuals than is noted in the literature as studies using a line bisection task; where participants determine the midpoint of a horizontal line have shown right and left biases to exist (Braun & Kirk, 1999; Cowie & Hamill, 1998; Manning, Halligan & Marshall, 1990). This interpretation has received support from a recent study (Varnava, Dervinis & Chambers, 2013) in which continuous

Theta Burst Stimulation (cTBS) was applied to the left and right angular gyrus (AG) during a line bisection task. Participants who demonstrated an RPB, by bisecting the line to the right of the midline, revealed an exaggerated rightward bias (leftward neglect) when their right AG was stimulated. Contrastingly though, when cTBS was applied to either the left or right AG of LPB participants it had no effect on bias, which suggests that the LPB, and potentially neglect of the right side, is not controlled by the AG. Instead, as has been demonstrated using a series of tasks on stroke patients (Suchan & Karnath, 2011), lesions to cortical areas typically associated with serving language (the left superior and middle temporal gyri, inferior parietal lobule and insula) result in neglect to the right, and therefore a bias to the left side. This shows that areas in the LH may contribute to spatial orienting to the left, whereas the AG in the RH contributes to spatial orienting to the right. Research is now required to ascertain whether these same areas in the LH and RH impact on right and left biases of perception during face processing.

The eye movements of participants expressing an RPB have not been investigated previously. This analysis revealed that people who typically judged the gender of the chimeric from the right side did not demonstrate an initial saccade or proportion of fixations eye movement bias to the right in either time condition. Only participants classified as having either a weak or strong LPB made their first saccade to the left. Furthermore (with the exception of the strong left bias group when basing their judgment on the left side in the limited time condition), the side of the face used for a gender judgment had no bearing on the proportion of fixations made to that side. As is clear from Table 5 there is a non-significant trend in both time conditions for the strong left group to look for longer at the left than the right side of the face when their decision was based on the left side and also when their decision was based on the right side. The right biased group showed the opposite pattern, a trend was revealed for this group to look for longer at the right side than the left whichever side of the face their decision was based on. Consequently, both the assertion that perception accompanies attention, along with the observation that an initial leftward eye movement independent of perceptual bias (Butler et al., 2005) appear too simplistic since the association between gaze and perception is only consistently evident in those with an LPB.

It is unclear why the participants in this current study did not demonstrate a left lateral eye movement bias for fixation duration when they also judged from the left side of the face, as Butler et al.'s (2005) participants clearly did. The same experiment was conducted, using the same stimuli and apparatus, and the younger adults were of the same age as Butler et al.'s. Potentially the current cohort contained an unusually high number of participants with an RPB and this acted to reduce the leftward eye movements typical during face processing. However, this is unlikely as a cross sectional design was used and a similar number of these right bias participants were recruited in both samples. Alternatively, it is possible that the majority of the young participants recruited by Butler et al. (2005) had a strong LPB since the movement patterns they reported are similar to those in the strong left bias group.

The unequal gender split in this study warrants comment. Previous researchers using the same stimuli as we used in this current experiment have recruited unequal groups of males and females when assessing perceptual and eye movement biases. Butler et al. (2005) recruited 20 participants, 4 of whom were males, Butler and Harvey (2008) recruited 22 younger adults (10 males) and 14 older adults (3 males) and Butler and Harvey (2006) recruited 17 adults (7 males). Butler and colleagues did not assess the impact of participants' gender on biases of perception or eye movements in any of these studies as previous research does not consistently indicate that the viewer's gender has impact. However, Luh et al. (1991) using different stimuli found no effect of participants' gender on judgements of gender and emotion from chimeric faces. In Parente and Tommasi's (2008) study the same laterality pattern was evident for male and female participants when judging the gender of chimeric images with both genders demonstrating a LPB. Similarly, when shown happy/sad chimeric faces, judgements of emotion and eye movement behaviour was not affected by the participants' gender (Phillips & David, 1997). In contrast though Mertens et al. (1993) found that female participants had a significantly stronger left eye movement bias than males, therefore future researchers should recruit equal numbers of male and female participants to explore this effect further.

In conclusion the results of this present study show that older age did not weaken the LPB or eye movement bias. Both age groups demonstrated a LPB and their initial saccades were also biased to the left in both time conditions. Proportionally more saccades were made when the gender judgment was also based on the left side, age and time condition did not affect this. When viewing time was limited to 1000ms initial saccades, number of fixations and fixation duration were positively associated with perceptual bias. The relationship between eye movements and perceptual bias was not as strong in the freeview condition, initial saccades were the only eye movements associated with perceptual bias. While the majority of the population were biased to the left when judging the gender of faces, approximately a quarter judged from the right and this did not appear to be age dependent. Additionally, an LPB is accompanied by an initial saccade to the left and a strong LPB is also accompanied by proportionally more fixations to the left side. An RPB though, is not accompanied by this eye movement behaviour which indicates that the same neural mechanisms may underlie gaze and perception in the right, but not left hemisphere. Further work investigating this is now required.

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Table 1.

Mean proportion (SD) of LPB and left initial saccades to chimeric images, and significance of one-sample t-tests against chance (.5).

Group	*n*	Freeview	*n*	1000ms view
		Perceptual Bias		
Younger adults	32	.55 (.10)**	24	.56 (.10)**
Older adults	31	.53 (.06)**	22	.53 (.07)
		Initial Saccades		
Younger adults	32	.62 (.31)*	24	.65 (.27)*
Older adults	31	.65 (.30)*	22	.63 (.28)*

Note. *Proportions >.5 indicate a leftward bias.* **p<.01, *p<.05.

Table 2.

Correlations between perceptual bias, eye movements, age and handedness.

	Freeview Condition				
	Initial Saccade	Proportion of Fixations	Fixation Duration to the Left	Handedness	Age
Perceptual Bias	.27*	.15	.01	-.08	.04
	1000ms Condition				
	Initial Saccade	Proportion of Fixations	Fixation Duration to the Left	Handedness	Age
Perceptual Bias	.34*	.47**	.56***	-.04	.11

***$p < .001$, **$p < .01$, *$p < .05$.

Table 3.

Mean proportion (SD) of left initial saccades per bias group. Statistical analysis conducted through one-sample t-tests against .5 (chance).

	Initial Saccades			
Perceptual Bias Group	*n*	Freeview	*n*	1000ms View
Strong Left	12	.73 (.32)*	10	.71 (.25)*
Weak Left	30	.63 (.30)*	19	.68 (.26)*
Right	12	.49 (.24)	12	.52 (.29)

*$p < .05$

Table 4.

Proportion of leftward fixations for left and right response judgments.

Group	Proportion of fixations: Freeview, Left judgment		Proportion of fixations: 1000ms view, Left judgment	
	Left judgment	Right judgment	Left judgment	Right judgment
Strong Left	.56 (.13)	.53 (.14)	.59 (.10)*	.58 (.14)
Weak Left	.52 (.11)	.50 (.11)	.53 (.09)	.53 (.10)
Right	.48 (.13)	.42 (.15)	.46 (.15)	.46 (.15)

Note. Values greater than .5 indicate proportionally more fixations to the left.*$p < .05$.

Table 5.

Mean (SD) fixation duration (ms) to the left and right face sides according to the side used for a judgment response.

	Duration of Fixations Freeview			
	Left Judgment		Right Judgment	
Group	Left Side	Right Side	Left Side	Right Side
Strong Left	855 (505)	700 (238)	839 (565)	807 (272)
Weak Left	1158 (717)	1058 (615)	1182 (816)	1261 (883)
Right	935 (410)	954 (416)	861 (467)	1010 (438)
	Duration of Fixations 1000ms			
	Left Judgment		Right Judgment	
	Left Side	Right Side	Left Side	Right Side
Strong Left	405 (55)	263 (78)	406 (61)	277 (79)
Weak Left	337 (66)	323 (97)	335 (59)	327 (100)
Right	299 (96)	352 (116)	290 (106)	350 (112)

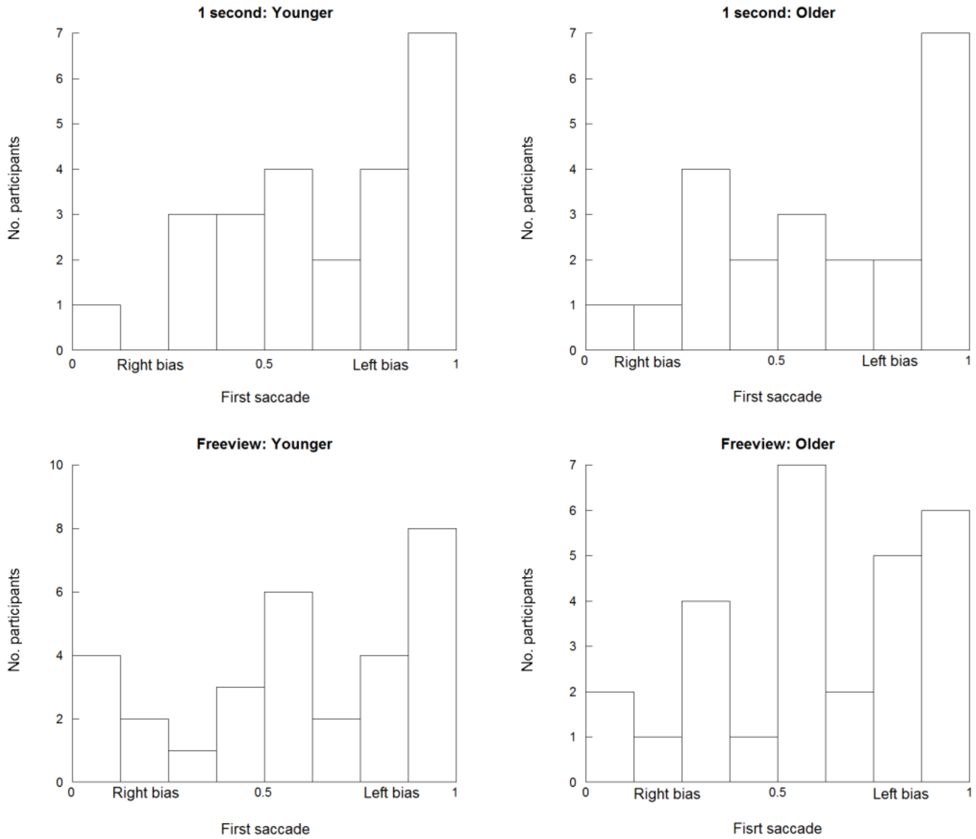

Figure 1. Mean proportion of initial saccades for younger and older adults in each time condition.

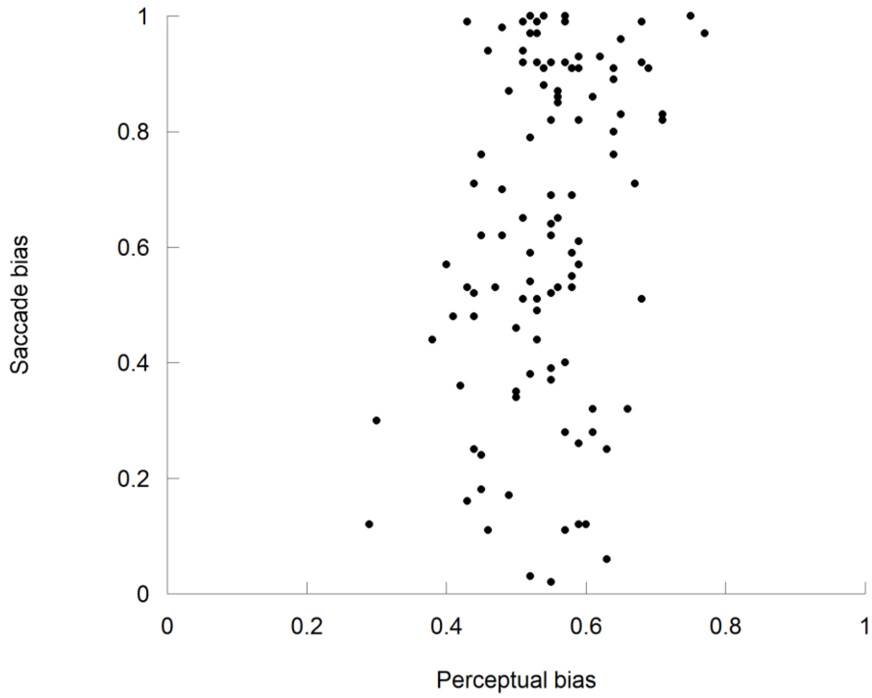

Figure 2. The association between the mean proportion of perceptual and initial saccade biases across both time conditions. Values > .5 indicate a left bias and values < .5 right bias.